

To appear in William Maxwell seminar of Mechanical Engineering, University of Kentucky, Lexington,  
Sep 23, 1999

## Advanced Actuation for the Millennium - Challenge and Opportunity

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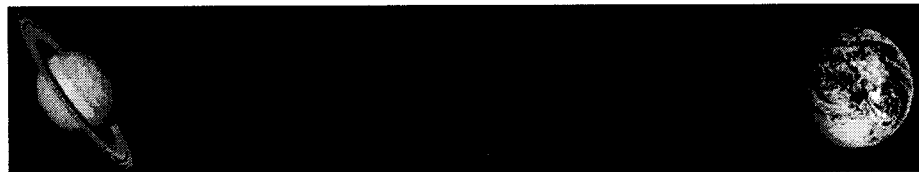
### ABSTRACT

Through the demanding of automation and miniaturization in many applications, it can be seen that the need of advanced passive or active actuation devices will be increased tremendously. On the other hand, the traditional used rotary electromechanical motor has been developed through the passed century and almost stretched to its functional limit. This motor can hardly meet the exigent requirements such as high torque density, low speed, no magnetic interference, miniaturization, simplification (no mechanical coupling), and so forth. Thus, alternative actuation devices have been developed with different operation principles such as piezoelectric motors, shape memory actuators, and artificial muscles or with different operation styles such as linear motors, planar motors, and hybrid motors to provide unachievable functions by the traditional electromagnetic motors. This paper reviews a variety of advanced actuation devices and their potential applications and challenges for the coming era.

# **ADVANCED ACTUATION FOR THE MILLENNIUM – Challenge and Opportunity**

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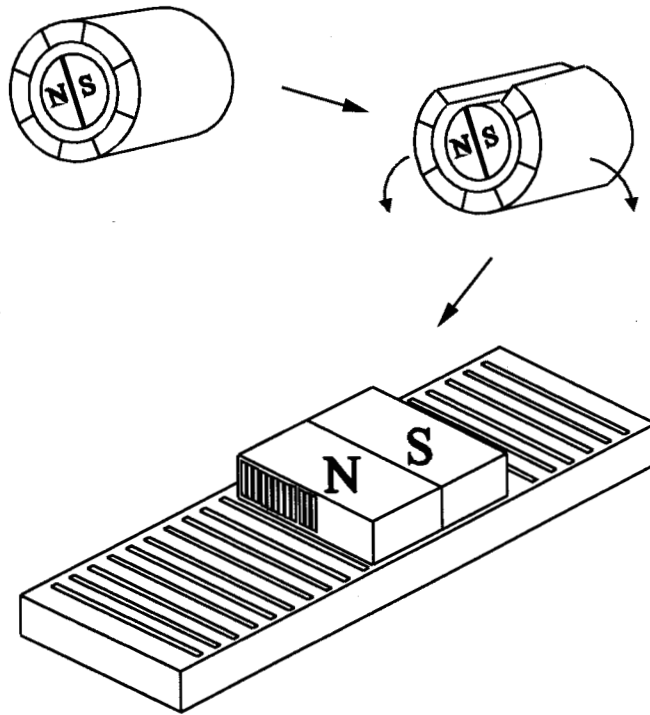
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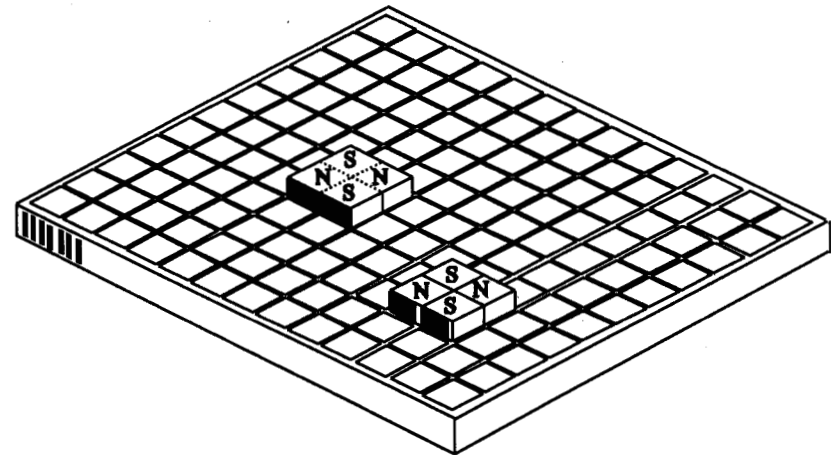
# Linear Motors

- The same electromagnetic force that produces torque in a rotary motor also produces direct linear force in a linear motor.
- A permanent magnet DC linear motor is similar to a permanent magnet rotary motor and an AC induction linear motor is similar to a squirrel cage induction motor.
- It follows that linear motors utilize the same amplifiers and controllers as rotary motors. And similar to a rotary motor with a rotary encoder, linear motor positioning feedback is provided by a linear encoder.

# Linear Motors



Single Axis Linear Motor



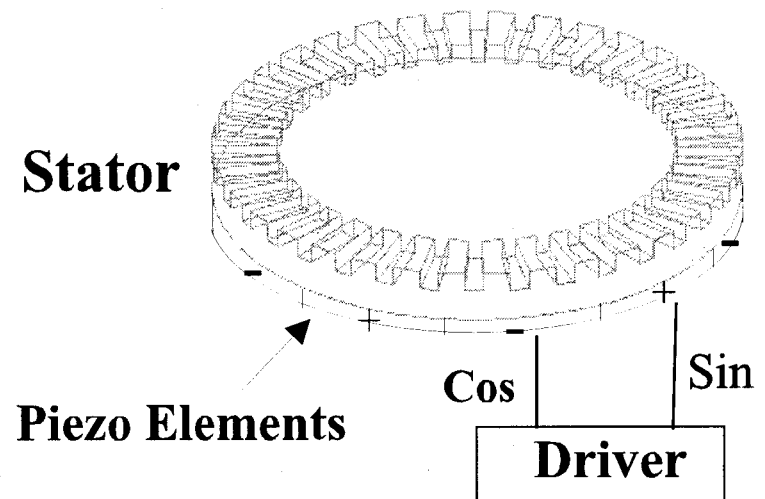
Planar Linear Motor

# **Linear Motors**

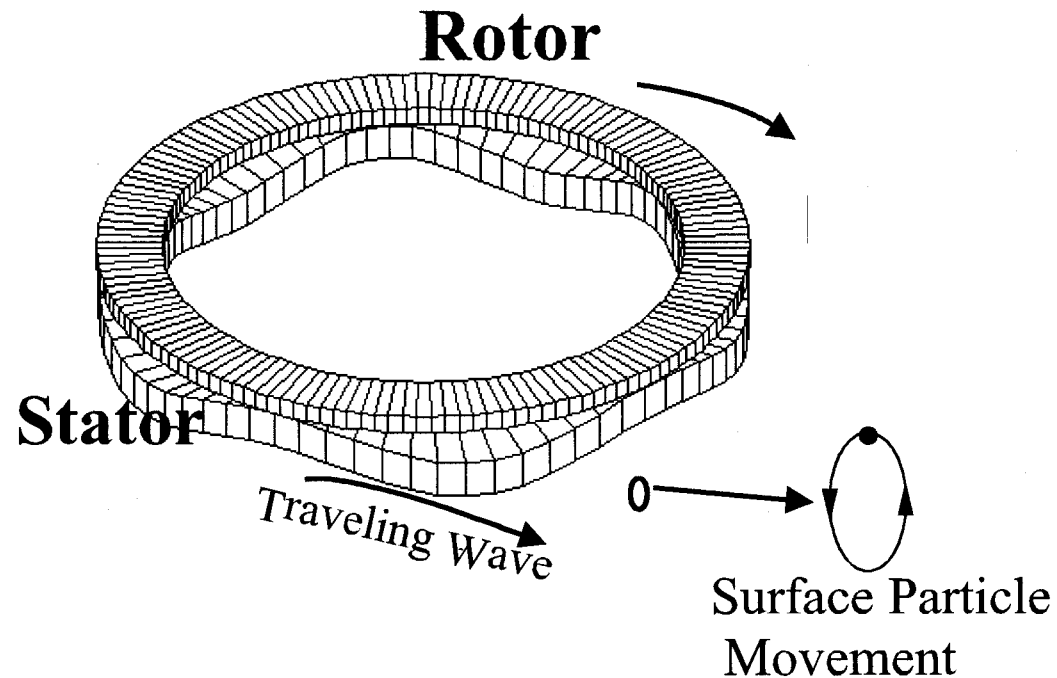
- **Simplicity only one moving part, no mechanical linkages**
- **Compact**
- **High accuracy, high resolution**
- **High velocity and acceleration**
- **Rapid response**
- **Direct drive**
- **Non-contact (air bearing type)**
- **No travel limits, as long as flatness and straightness are maintained**

# Piezoelectric Motors

- **Type:** Ultrasonic/Resonant, Standing Wave, Travelling Wave
- **Advantages:**
  - High Torque: 1.3 N-m
  - Low speed: .5-90 rpm
  - No Gear, no brake
  - High Power densities
  - Light weight.
- Excellent for miniaturize spacecraft



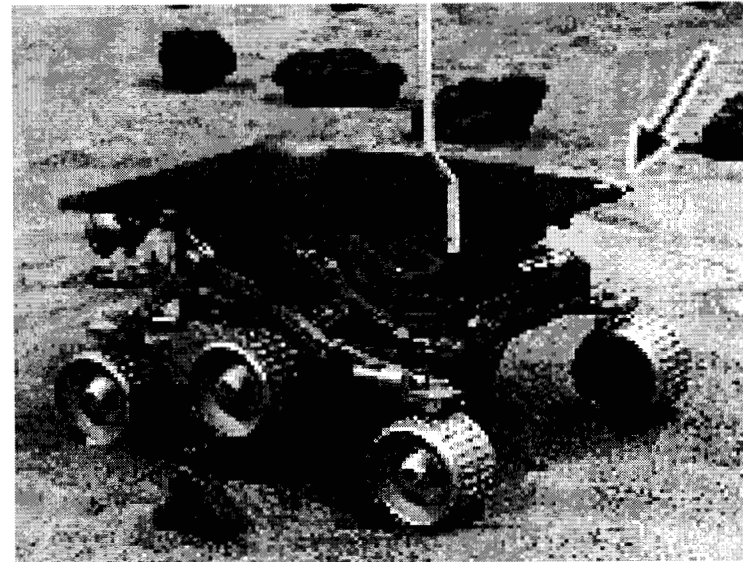
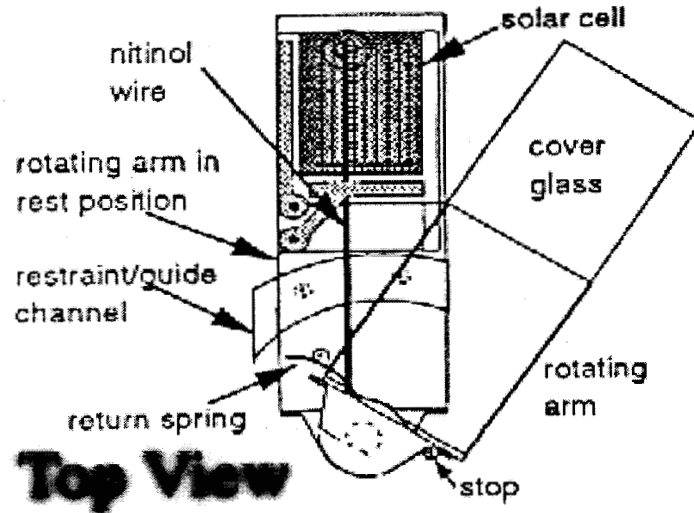
# Ultrasonic Motors



## Principle of Ultrasonic Motors

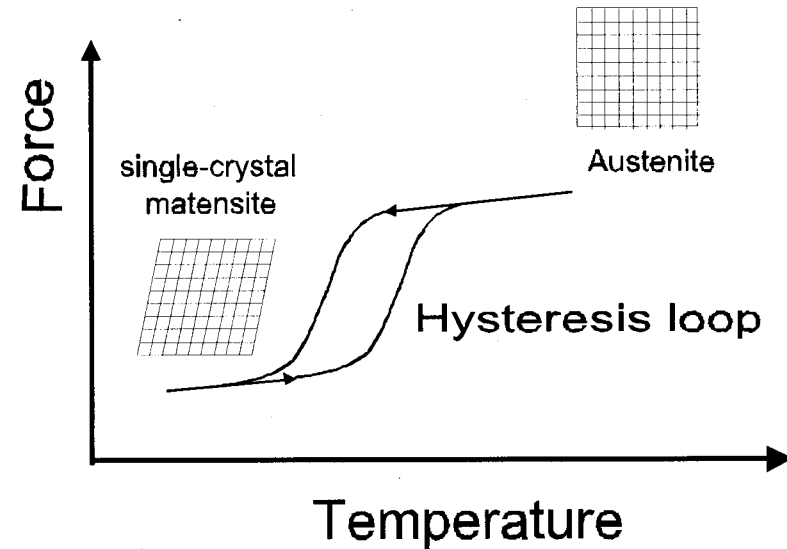
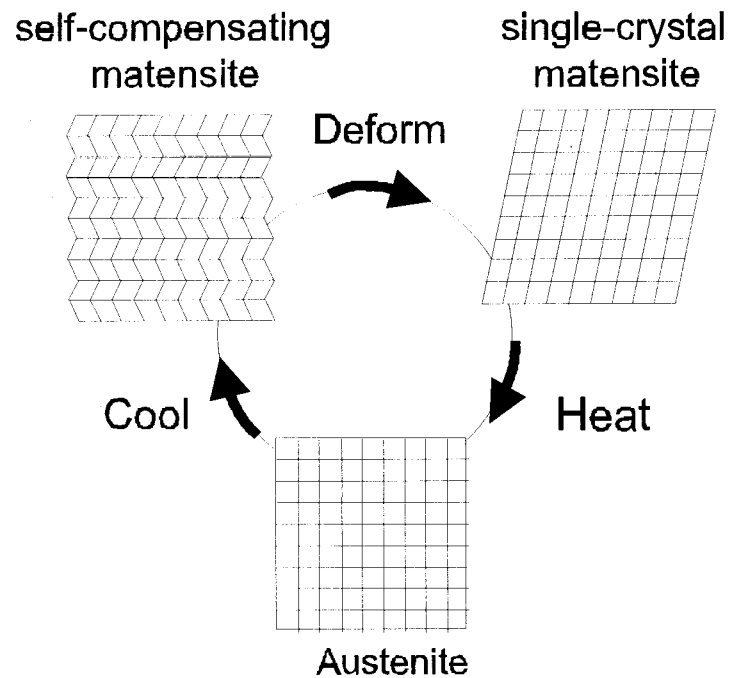


# Shape Memory Material Actuators



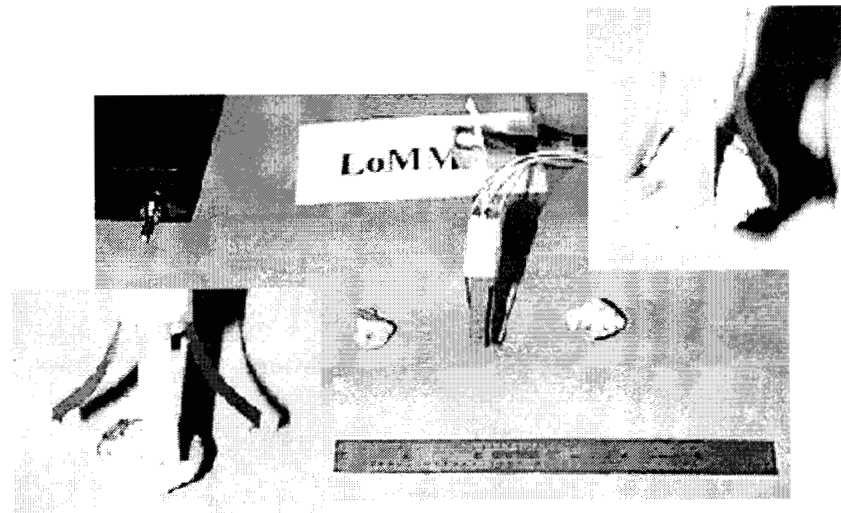
(Courtesy of Geoffrey Landis and Phillip Jenkins at NASA's Glenn Research Center)

# Shape Memory Material Actuators



# Electrostrictive Actuators

- Artificial muscles
  - cheap
  - durable
  - low power consumption (50 milliwatts)
  - Not very strong.
  - Bio type actuations



(Courtesy of Dr. Yoseph Bar-Cohen (JPL))

## Challenge and Opportunity

- Large elastic deformation
- Nonlinear and Hysteresis behaviors of materials
- Contact problems
- Electro-thermal-mechanical-magnetic coupling effect
- Survivability, Controllability
- Power supply and drivers
- Feed back systems